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RESEARCH ARTICLE

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Are all rivers equal? The role of education in attitudes towards temporary and perennial rivers

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Abstract

1. Temporary rivers (TRs) are prevalent, biodiverse ecosystems yet often overlooked and underprotected. This may be because inadequate understanding of their ecosystem services leaves them undervalued by society. However, evidence of negative attitudes towards TRs is scant.
2. We investigated the strength and extent of negative attitudes by surveying undergraduate students from Australia, UK, and USA on their agreement (positive attitude) or disagreement (negative attitude) with statements about the ecosystem services, moral consideration, and protection of perennial and TRs. Students were surveyed at the start and end of teaching units covering environmental topics.
3. Disagreement with statements was uncommon (17% across all statements and surveys) and attitudes towards TRs were mostly positive. However, attitudes towards perennial rivers were more positive, particularly in comparison with non-flowing TRs and with regard to their aesthetic value and recreational amenity. There were no significant differences in attitudes towards perennial and TRs in one teaching unit in Australia, and responses were more often more positive at the end of teaching units in the UK.
4. Our study indicates education can change attitudes. The overall positive response to statements may reflect underlying environmental awareness and pre-existing interest of participants enrolled in environmental and biology degrees, but not necessarily specific knowledge of TRs. General environmental education across the wider community could improve attitudes towards TRs, particularly when they are not flowing or in regions where they are uncommon or inconspicuous, and could support positive protection measures and innovative, inclusive management.

KEYWORDS
ecosystem services, flow intermittence, intermittent rivers, management, survey, temporary rivers, values

1 | INTRODUCTION

Temporary streams and rivers are waterways that stop flowing at some point in space and time. Found on every continent, these ecosystems range from small headwater streams to large lowland rivers and stop flowing on their surface for geological, climatic, and/or human-induced reasons (Costigan et al., 2017). A wide variety of terms for temporary rivers (TRs) has evolved, the most common relating to the duration and predictability of flow, with *seasonal* and *intermittent* referring to rivers that stop flowing predictably, and *episodic* and *ephemeral* to those that flow less predictably, for example, in response to rare local rainfall (Uys & O'Keeffe, 1997; Williams, 2006). Other terms are more local, for example, *arroyo* (USA), *rambla* (Spain), *wadi* (northern Africa), and *winterbourne* (UK), reflecting the long-standing connection between humans and rivers manifest through language (Steward, Schiller, Tockner, Marshall, & Bunn, 2012). Here, we use the term *TRs*, to refer collectively to all these systems, and *perennial rivers (PRs)* for those with continuous surface flow.

The ecological study of TRs dates from at least the early 20th century yet, despite being the most widespread type of river on Earth and an ongoing surge in interest, TRs have received less scientific attention than their perennial counterparts (Leigh et al., 2016). Furthermore, they are becoming more prevalent in many regions in response to drying climates and growing human demand for water (Chiu, Leigh, Mazor, Cid, & Resh, 2017; Döll & Schmied, 2012; Tooth, 2000). However, TRs are among the most underprotected and poorly managed of all freshwater ecosystems (Acuña et al., 2014; Leigh et al., 2016; Marshall et al., 2018). This lack of management and protection is concerning because TRs provide habitat not only for aquatic biota, but also for terrestrial biota as their riverbeds fluctuate between wet and dry phases. Ecological research is also revealing that these ecosystems support several unique, endemic, and/or locally rare species, thereby contributing to regional biodiversity and meriting their inclusion in conservation plans (Bogan, Boersma, & Lytle, 2013; Sánchez-Fernández et al., 2008).

Underprotection and poor management of TRs may transpire because society holds these ecosystems in low esteem and as indicators of environmental degradation (Acuña, Hunter, & Ruhí, 2017), in contrast to the perceived higher value of PRs, which flow all year round (Armstrong, Stedman, Bishop, & Sullivan, 2012). Notably, Armstrong et al. (2012) found that flow permanence positively influenced the attitudes of landowners towards the streams on their properties, and their concern over water quality. In addition, understanding of the ecosystem attributes and services provided by TRs, including their biodiversity, recreational opportunities, and their aesthetic value, is limited and has only recently been addressed from scientific and management perspectives (Datry et al., 2018; Steward, Negus, Marshall, Clifford, & Dent, 2018). Limited understanding may have hindered scientific and, by extension, public appreciation of such attributes and services, creating a negative feedback cycle wherein TRs have been understudied hence undervalued, and undervalued hence understudied. The undervaluation of TRs is often cited as the reason for their limited protection (e.g. Acuña et al., 2017; Koundouri, Boulton, Datry, & Souliotis, 2017); however, empirical evidence that TRs are underappreciated is scant (Armstrong et al., 2012). Furthermore, public concern for and attitudes towards TRs may be expected to vary by region. Positive impressions may be more likely to occur in regions where TRs are common, such as in Mediterranean and arid climate zones (Steward et al., 2012), and undervalued in regions where such rivers are less common or less noticeable components of the landscape, such as in oceanic-temperate zones (Stubbington et al., 2018).

Here, we aimed to investigate the nature and extent of attitudes towards PRs and TRs, including the latter when they have stopped flowing, and more specifically the role that education can play in attitudes towards rivers. Our objective was to surmise what might drive positive change in attitudes, which may provide insight on strategies to improve river management. We surveyed undergraduate students in different regions of Australia, the UK, and USA, to ascertain the potential role that education can play in forming and changing attitudes, and we considered their attitudes as positive or negative evaluations of PRs and TRs, following Dietz, Fitzgerald, and Shwom (2005). We hypothesized that attitudes towards PR would be the most positive and attitudes towards TRs when not flowing the least positive. Furthermore, we hypothesized that attitudes towards TRs would improve and become more similar to those towards PRs following courses of environmental education by the participants. Our study contributes novel empirical evidence towards attitudes towards TRs, which heretofore have generally been assumed but rarely evidenced.

2 | MATERIALS AND METHODS

2.1 | The survey, experimental design, and participant demographics

Surveys can provide a consistent way of measuring attitudes across individuals, countries, and time (before/after an intervention; for example, Lovelace & Brickman, 2013). Our surveys comprised 10 statements (Table 1) on which participants were asked to rate their agreement or disagreement, on a Likert scale of 1 to 5 (*Strongly disagree* = 1, *Disagree* = 2, *Neutral [i.e. neither agree nor disagree]* = 3, *Agree* = 4, *Strongly agree* = 5), such that more positive response values equated to more positive attitudes. We included an 'I don't understand' check-box option with each statement to ensure neutral responses were not a reflection of poor understanding. Statement 1 concerned the participants' sense of moral obligation to maintain the ecological condition of rivers and Statement 2 whether they would be upset if their own activities harmed a river. The next two

TABLE 1 Survey statements regarding perennial rivers (PR), temporary rivers in general (TR), and TR specifically when they have no surface-water flow (TRNF) and the river type to which each statement applied

Statement number	Statement	River type
1	I have a moral obligation to maintain the ecological condition of this type of river	PR, TR
2	I would be upset if my activities harmed this type of river	PR, TR, TRNF
3	Conservation of this type of river is important	PR, TR
4	Degraded rivers of this type need restoration	PR, TR
5	Taking water from this type of river is an environmental concern	PR, TR, TRNF
6	Using this type of river for human activities is an environmental concern	PR, TR, TRNF
7	This type of river has aesthetic value	PR, TR, TRNF
8	This type of river is important for biodiversity	PR, TR, TRNF
9	This type of river provides ecosystem services	PR, TR, TRNF
10	This type of river provides recreational amenity	PR, TR, TRNF

TABLE 2 Glossary of terms provided to participants

Term	Definition and description
Aesthetic value	Something you appreciate visually has aesthetic value
Biodiversity	The variety of all life (including plants, animals, fungi, bacteria, etc.) in the world or in a particular environment or habitat
Conservation	Conservation involves specific management actions and/or policies that aim to protect species, habitats, and/or ecosystems from degradation
Degradation	Deterioration of an environment or habitat through depletion or pollution of resources such as air, water, and soil; damage to or the destruction of ecosystems and the loss of species; a reduction in the capacity to produce ecosystem services
Ecosystem services	Benefits that humans derive from ecosystems. They include ‘provisioning services’ such as water and food, ‘regulating services’ such as water purification, soil-erosion control and nutrient cycling, and ‘cultural services’ including spiritual and scenic benefits
Perennial rivers	Rivers that flow all year round, every year
Recreational amenity	Something that has recreational amenity can be used, or provides opportunities, for recreation
Restoration	A practice that aims to assist the recovery of ecosystems from disturbance by restoring degraded biodiversity, habitats, and/or ecosystems to a target level through specific management actions and/or policies
River	A natural channel in the landscape that conveys water from upstream to downstream. Rivers come in all shapes and sizes and are known by many names, e.g. streams, brooks, creeks, etc.
Temporary rivers	Rivers that stop flowing for a period of time. This means at times the river is flowing but at other times the riverbed can be dry, sometimes with pools of surface water in between sections of dry riverbed. When a temporary river starts flowing again, the riverbed becomes wet and flowing water reconnects pools. TR can remain dry (with or without pools) for days, months, or years in between times of flow, which also vary in duration

statements reflected attitudes to management actions; Statement 3 concerned conservation and Statement 4 restoration. Statement 5 explored attitudes about taking water from rivers, and Statement 6 about using rivers for (unspecified) human activities. The final four statements concerned the aesthetic value (Statement 7), biodiversity importance (Statement 8), ecosystem services (Statement 9), and recreational amenity of rivers (Statement 10). We aligned our descriptions of ecosystems services with those of the Common International Classification of Ecosystem Services (CICES v4.3; http://cices.eu/) because it is used widely, provides standardized descriptions, and is comprehensive and non-repetitive, recognizing three broad categories of services: provisioning, regulating, and cultural. Statement 9 thus considered all categories together. We included the more specific Statements 7 and 10 on cultural services because the aesthetic value and recreational amenity of rivers are the most-often studied cultural services of aquatic systems and are increasingly recognized as important topics of public concern (Hernández-Morcillo, Plieninger, & Bieling, 2013; Young, 2010).

All statements were made in relation to (a) PRs, (b) TRs, and (c) TRs specifically when they have no surface-water flow (TRNF; when the river bed may be completely dry or contain isolated pools of water), except for Statements 1, 3, and 4, which were made in relation to PRs and TRs only (totalling 27 statements per survey; Table 1). All surveys contained a glossary of terms (Table 2). We did not supply further information, for example photographs, on the different river types and flow states to limit introduction of bias beyond

TABLE 3 Country, region, and main climate class associated with where surveys were conducted, teaching units in which participants were enrolled along with the number of surveys completed and the respective teaching-unit response rates and degree years, with participant demographics shown as percentages

Survey	Country (region)	Climate	Unit (*n, response rate %, degree year*)	Gender		Age group			Highest qualification				Country lived in most			
				M	F	18–29	30–49	50–64	SSG	TTV	UG	PG	Aust.	UK	USA	Fr.
1	Aust. (Q)	Subtropical-Arid	River ecosystems (9, 45, second)	67	33	78	22	0	67	0	11	11	78	11	11	0
			Community ecology (10, 53, third)	40	60	80	20	0	50	30	20	0	90	0	10	0
	UK (EM)	Oceanic temperate	Freshwater ecosystems (10, 91, second)	50	50	100	0	0	100	0	0	0	0	90	0	10
	UK (WM)	Oceanic temperate	River ecosystems (21, 73, first)	67	33	100	0	0	100	0	0	0	0	95	5	0
			River management (16, 84, third)	56	44	94	0	6	94	6	0	0	0	100	0	0
	USA (CA)	Mediterranean-Arid	Biostatistics (18, 100, third–fourth)	17	83	100	0	0	100	0	0	0	0	0	100	0
	USA (KY)	Humid subtropical	Ecology (9, 100, second–fourth)	78	22	100	0	0	100	0	0	0	0	0	100	0
			River management (16, 100, second–fourth)	31	69	100	0	0	88	0	13	0	0	0	100	0
	All		Mean	51	49	94	5	1	87	5	5	1	21	37	41	1
	All		*SD*	20	20	10	10	2	19	11	8	4	39	48	49	4
2	Aust. (Q)	Subtropical-Arid	River ecosystems (9, 64, second)	56	44	100	0	0	56	0	44	0	89	0	11	0
			Community ecology (6, 75, third)	50	50	83	17	0	17	50	33	0	83	0	17	0
	UK (EM)	Oceanic temperate	Freshwater ecosystems (11, 100, second)	55	45	100	0	0	100	0	0	0	0	91	0	9
	UK (WM)	Oceanic temperate	River ecosystems (21, 73, first)	67	33	100	0	0	100	0	0	0	0	95	5	0
			River management (16, 84, third)	56	44	94	0	6	94	6	0	0	0	100	0	0
	USA (KY)	Humid subtropical	Ecology (9, 100, second–fourth)	78	22	100	0	0	100	0	0	0	0	0	100	0
			River management (16, 100, second–fourth)	31	69	100	0	0	88	0	13	0	0	0	100	0
	All		Mean	56	44	97	2	1	79	8	13	0	25	41	33	1
	All		*SD*	14	14	6	6	2	32	19	19	0	42	51	46	3
1 and 2	All		Mean	53	47	95	4	1	83	6	9	1	23	39	37	1
	All		*SD*	18	18	8	8	2	25	14	14	3	39	48	46	3

Note. PR: perennial river; TR: temporary river; TRNF: temporary river when not flowing; Aust.: Australia; Q: Queensland; EM: East Midlands of England; WM: West Midlands of England; CA: California; KY: Kentucky; Fr.: France; SSG: secondary (high) school graduate; TTV: trade/technical/vocational training; UG: university undergraduate degree; PG: university post-graduate degree; *n*: number of participants surveyed; *SD*: standard deviation.

the participants' own mental reference points, such as the appearance of rivers when not flowing, which can range from large pools of surface water to completely dry riverbeds (Table 2).

Participants were enrolled in undergraduate degrees in biology, ecology, environmental sciences, environmental management, and/or geography at tertiary education institutions in Australia (one in southeast Queensland), the USA (one in California and one in Kentucky), and the UK (two in central England) and were at various stages of degree completion (Table 3). The different countries and regions within them covered a range of temporary river prevalence and climate classes (Table 3): highly prevalent and/or conspicuous TRs in arid to subtropical Australia and Mediterranean-climate California, and less prevalent or conspicuous TRs of oceanic-temperate UK and humid subtropical Kentucky, USA (Poff, 1996; Kennard et al., 2010; Stubbington, England, Wood, & Sefton, 2017). Participants were surveyed twice: once at the start of a teaching unit (i.e. a credit-bearing unit of taught content, equivalent to a 'module' in the UK, and a 'course' in Australia and the USA; Survey 1), and again at the end of the unit (Survey 2). Although the units varied in topics covered and were delivered by different instructors (Table 3; Supplementary Information S1), our broad hypothesis was that attitudes towards TRs would become more similar to those of PRs following courses of environmental education (i.e. we did not a priori stipulate the specific subjects taught or their mode of delivery). Survey 2 was not conducted at the end of the *biostatistics* unit in California; this unit did not have a strong environmental focus (Supplementary Information S1). Participants enrolled in more than one unit at any of the institutions were only surveyed in one of those units. Participant demographics were characterized by an additional set of survey questions (Table 3). All participants remained anonymous and surveys were conducted following human-research ethical standards (see Acknowledgements for details of ethical clearances).

Out of 142 surveys distributed in Survey 1, 109 were returned completed (77% response rate overall, with a teaching-unit mean of 81 ± 22% per unit; Table 3). Survey 2 had a higher response rate, with 88 of the 107 distributed surveys returned completed (82% overall, with a teaching-unit mean of 85 ± 15%; Table 3). In both cases, the response rate was higher than that considered suitable for survey inference (60%; Johnson & Wislar, 2012). Two participants surveyed in the *biostatistics* unit (California) and one in the *river management* unit (Kentucky) did not understand Statement 5 for TRNF, and one participant in the *freshwater ecosystems* unit (UK) did not respond to Statement 10 for TRNF.

2.2 | Data analysis

We tested whether responses to statements from Survey 1, which encompassed all eight units, differed depending on the river type to which the statements referred (PR, TR, or TRNF) using nonparametric Wilcoxon tests for unpaired data. Such tests were appropriate and follow best practice (Lovelace & Brickman, 2013) because the survey data were not metric, that is, the values 1 to 5 represented the ordinal-scale responses of *Strongly disagree* to *Strongly agree*. We used a Monte Carlo resampling procedure to estimate the p-values for these tests because our participants were not selected randomly from the broader population (i.e. they were students at tertiary education institutions enrolled in specific degree programs). We conducted separate pairwise tests for each survey statement (PR vs. TR, PR vs. TRNF, TR vs. TRNF) within each unit.

To determine if the responses to statements differed between Survey 1 and 2 for each unit, we used nonparametric tests with the Monte Carlo resampling procedure (for the reasons stated above). We used the Wilcoxon sign test for paired data, which was the appropriate method to test for differences in responses between survey rounds for units that involved repeated measures, (i.e. the same subjects participated in both surveys and were identifiable by a unique code). This included all units except the two in Australia, for which participants differed between survey rounds, and the *biostatistics* unit, for which participants were surveyed once only. For units in Australia, we used the Wilcoxon test for unpaired data to test for differences in responses between survey rounds (because the participants differed between survey rounds, that is, were unpaired). We performed a separate test (for paired or unpaired data, as appropriate) for each survey statement within each unit. All statistical analyses were implemented within the *coin* package in R statistical software (Hothorn, Hornik, Wiel, & Zeileis, 2006,2008; R Core Team, 2017).

3 | RESULTS

3.1 | Differences between PRs and TRs, units, and countries (Survey 1)

In general, there was broad agreement that TRs are valuable and deserving of protection; with most statements engendering agreement or strong agreement (i.e. response values ranging from 4–5, indicative of positive attitudes), regardless of river type, unit, or country (Figures 1 and 2). Disagreement and strong disagreement with statements were rare (15% for TRNF, 5% for TR, 3% for PR in total across all statements; Figure 2). Most of the statistically significant differences in response values between river types, when they occurred, were for Statements 7–10 (aesthetic value, biodiversity importance, ecosystem services, recreational amenity), and 7 and 10 in particular, for which there was stronger agreement with statements (higher median values, indicating more positive attitudes) about PRs than TRs, particularly TRNF (all $p < 0.05$; Figure 1). Responses from participants enrolled in the *river ecosystems* unit in Australia were the only examples where there was no statistical evidence of differences in response values between PRs, TRs, and TRNF for any statement (all $p \geq 0.05$; Figure 1). There were only two examples where responses to statements about PRs were significantly lower in value than statements about TRs; Statement 5 (taking water) in the *freshwater ecosystems* unit (PR vs. TR; $p = 0.01$) and Statement 6 (using rivers) in the *biostatistics* unit (PR vs. TRNF; $p = 0.02$; Figure 1), indicating less agreement with these statements about PRs than about TRs or TRNF.

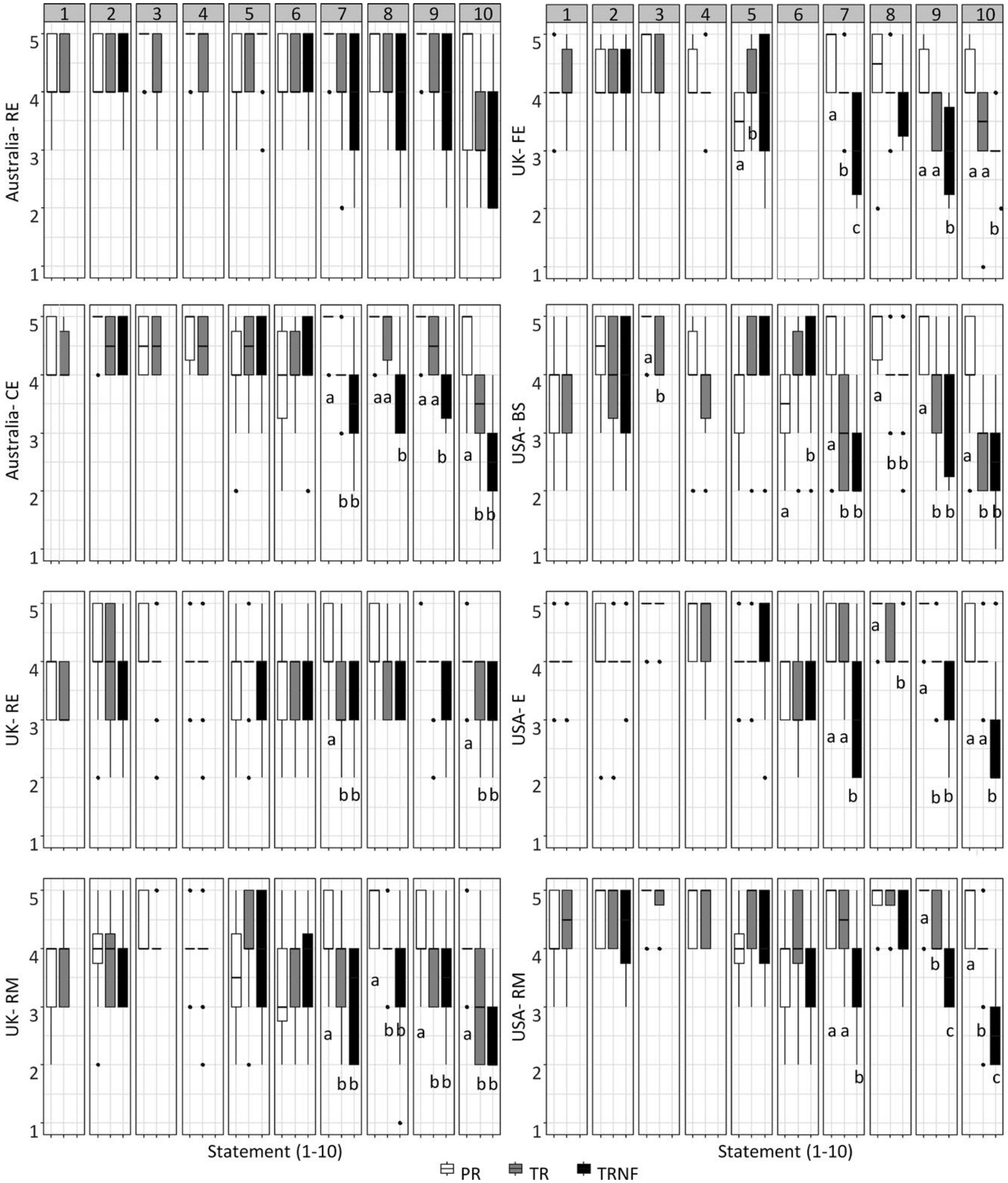

FIGURE 1 Response values on a Likert-scale reflecting strong disagreement (1) to strong agreement (5) with statements 1–10 about rivers from participants surveyed at the start of a teaching unit in Australia, UK, or USA (Survey 1). Statements 1–10 are described in Table 1. Units were on topics of biostatistics (BS), community ecology (CE), ecology (E), freshwater ecosystems (FE), river ecosystems (RE), or river management (RM). Different lower-case letters indicate statistically significant difference ($p < 0.05$) between responses to statements about perennial rivers (PR) versus temporary rivers (TR), PR versus TR specifically when not flowing (TRNF), and/or TR versus TRNF

3.2 | Differences between survey rounds (Survey 1 vs 2)

Regardless of river type, agreement with all statements together was consistently more common in Survey 2 than in Survey 1 (% *Agree* + % *Strongly agree*: 85 vs. 89 for PR, 77 vs. 83 for TR, 60 vs.

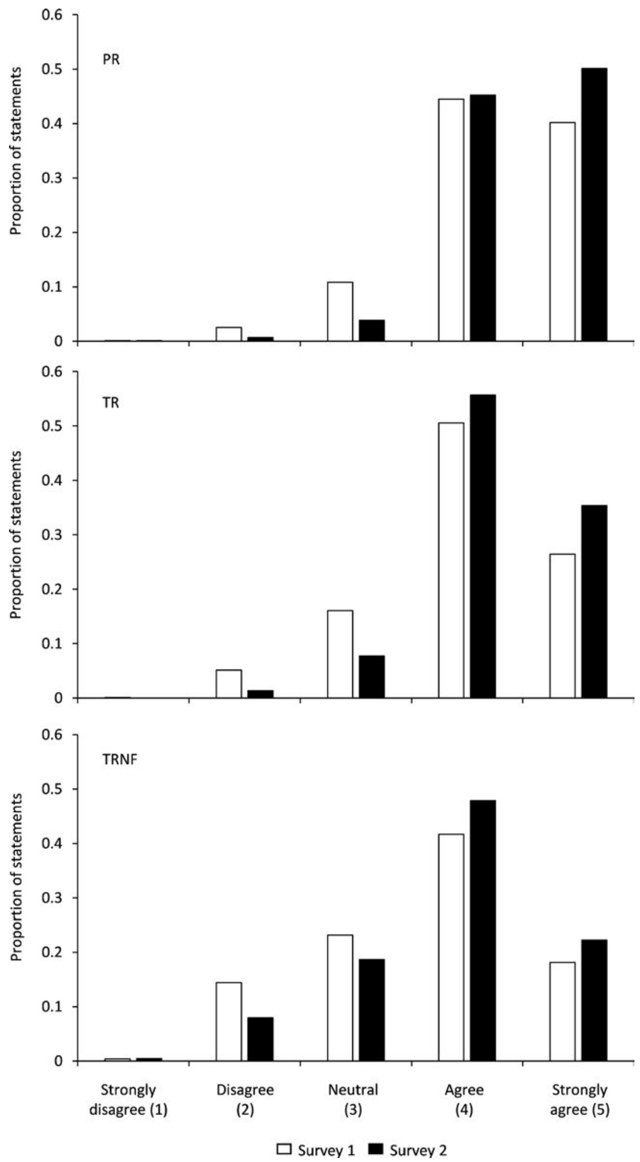

FIGURE 2 Proportion of all statements with which participants strongly disagreed, disagreed, neither agreed nor disagreed (neutral), agreed or strongly agreed, on a Likert scale of 1 to 5, in Survey 1 and Survey 2 for perennial rivers (PR), temporary rivers (TR), or TR when not flowing (TRNF)

64 for TRNF) and disagreement with statements consistently less common (% *Disagree* + % *Strongly disagree*: 3 vs. 0.8 for PR, 5 vs. 1 for TR, 15 vs. 8 for TRNF; Figure 2). For individual units, the greatest number of statistically significant changes in response values between surveys occurred in the West Midlands of England. Three statements engendered significant change in the *river management* unit (PR: statements 5 and 6, about taking water and using rivers; TR: 10, about recreational amenity) as did six statements in the *river ecosystems* unit (PR: 1 and 7–9, about moral obligations, aesthetic value, biodiversity importance, and ecosystem services in general; TR: 1 and 7, about moral obligations and aesthetic value). In each case, response values increased significantly from Survey 1 to Survey 2 ($p < 0.05$; Table S1) indicating that attitudes towards both PRs and TRs were more positive in Survey 2. However, there were no statistical differences in response values between surveys for either unit in Australia or for the *ecology* unit in Kentucky ($p > 0.05$ for each statement, whether about PRs, TRs or TRNF; Table S1).

4 | DISCUSSION

We found that surveyed participants held positive attitudes towards both TRs and PRs. Across all surveys, agreement with statements about each of these river types was high (up to 83% and 89%, respectively), although noticeably lower for statements about TRNF (up to 64%). This suggests that the participants may value and consider TRs and PRs similarly, at least when TRs are flowing. Surveyed participants were enrolled in undergraduate degrees in biology, ecology, environmental sciences, environmental management, and/or geography at tertiary education institutions and were thus relatively well educated; however, demographics varied between institutions, with many participants receiving their first formal education on freshwater ecosystems at the time of survey participation. The influence of environmental education, and particularly field-based education, on pro-environmental attitudes is well documented (e.g. Goldman, Assaraf, & Shaharabani, 2013; O'riordan, 1981; Volk & Cheak, 2003). Our study therefore provides evidence that environmental education can positively affect how students feel about PRs and TRs, irrespective of whether those ecosystems are covered explicitly in the material delivered. This is important because student's attitudes towards rivers may affect their future work in environmental science and management across public, private, and third sectors. Educational programmes that recognize both PRs and TRs as ecosystems that support high biodiversity and imperilled species (e.g. Bogan, Hwan, & Carlson, 2015; Wigington et al., 2006), and that deliver services from which people benefit (Datry et al., 2018; Stubbington et al., 2018), are thus also likely to deepen understanding and further improve attitudes to better inform and positively influence the protection and management of these ecosystems (Koundouri et al., 2017).

Despite the overall positive response to statements about both TRs and PRs, responses to statements about PRs were the most positive (up to 89% agreement), particularly in comparison with TRNF (up to 64% agreement) and regarding statements about aesthetic and recreational provision, for which there were consistently significantly lower response values (indicating greater disagreement). These findings support our first hypothesis that attitudes towards PRs would be more positive than those towards TRs, especially when not flowing. The most obvious deviation from this finding was for the *river ecosystems* unit in Australia (Survey 1), where responses to statements about PRs, TRs, and TRNF did not differ in value. A high proportion of rivers in Australia are temporary, including in the region where those surveys were conducted (Kennard et al., 2010), and the commonness of and familiarity with such systems may be why responses were no different among river types, even for non-flowing TR. The cultural importance and recreational amenity of dry TRs in many parts of Australia is well-documented (Steward et al., 2012). However, responses in the *community ecology* unit in Australia did depend on river type, following the general trend of most to least positive for statements on PRs to TRNF, even though the participants in this unit had similar demographics to those in the *river ecosystems* unit and both units were delivered in the same geographical region (southeast Queensland). This suggests that attitudes towards PRs and TRs can differ amongst groups of individuals despite those groups having similar demographics, and that the more specific the subject of environmental education (e.g. river ecosystems as opposed to more general community ecology) the more specific the attitudes to different ecosystems may become.

Response values were often higher at the end of teaching units, supporting our second hypothesis that attitudes would improve following environmental coursework. For TRs this was particularly so in the UK. TRs are common and widespread in countries with oceanic climates, such as the UK, but are less well known and conspicuous than their counterparts in arid and Mediterranean-climate regions (Snelder et al., 2013; Steward et al., 2012; Stubbington et al., 2018,2017). This highlights the importance of providing opportunities to visit such systems and to learn about the environment and ecology, in general and specifically in relation to TRs, particularly in regions where they are scarce, cryptic, and/or projected to increase in prevalence due to climate change and/or increasing freshwater demands (Döll & Schmied, 2012; Stubbington et al., 2017). Linked with this is the need for scientists to better document TRs (e.g. in headwater regions; Beaufort, Lamouroux, Pella, Datry, & Sauquet, 2018); citizen science groups focussed on biological monitoring, water quality, or ecosystem services issues can assist such efforts (Buytaert et al., 2014; Datry, Pella, Leigh, Bonada, & Hugueny, 2016; Freshwater Ecology and Hydrology Management (FEHM) Lab Research Group, 2018).

Differences in attitudes towards PRs and TRs and the perceived benefits of these systems to society are understandable given the relatively limited public discourse on TRs. As more rivers transition from perennial to temporary, we may see a natural increase in their valuation as they become more conspicuous, common, or familiar components of the landscape. However, the opposite may also be true. We suspect that TRs may be viewed as signs of environmental degradation (e.g. a river once perennial, which through misuse has stopped flowing) instead of natural features of the landscape. The awareness of TRs, their origins and ecological significance can be increased not only through public education programs but also through media outlets. This could include production of high-profile scientific outputs (e.g. editorials and perspectives such as Creed et al., 2017; Marshall et al., 2018) and/or the use of social media to improve communication between scientists, the public, management agencies, and decision makers (Bik & Goldstein, 2013).

Our study provides new insight on attitudes towards TRs and the role that education can play in changing attitudes. By necessity, we surveyed a limited section of the population; demographic, teaching unit, and instructor effects may thus have contributed to the patterns we observed. For instance, the overall positive response to statements may reflect underlying environmental awareness and pre-existing interest of participants enrolled in environmental and biology degrees. Nevertheless, our results reflect an overall difference in attitudes towards rivers based on their flow conditions. We recommend that (a) future research document attitudes towards TRs more comprehensively, by (i) encompassing a wider cross-section of the community, ensuring adequate replication within regions and climate zones and (ii) controlling for confounding variables by standardizing the education provided between survey rounds and (b) researchers widen and improve their communication of scientific findings to non-academic audiences.

CONFLICT OF INTEREST

Nothing to declare.

ACKNOWLEDGEMENTS

Human research ethics approvals were granted to each author to conduct the surveys described herein, to share data with each other and publish results, by ethics committees and review boards at the respective institutions at which the surveys were conducted. Under the ethical clearances granted (Griffith University Project 2016/539, Centre College Project 163_Galatowitsch_Rivers, Nottingham Trent University Project 16-17/21, University of San Diego Project IRB-2017-190, and University of Worcester Project SH17180002), archiving and distribution of the raw data are prohibited. We thank our colleagues who provided us with the opportunity to distribute surveys at the start and end of units.

AUTHORS' CONTRIBUTIONS

C.L. conceived the original idea and design, which was developed and implemented by all authors. All authors collected the data and C.L. conducted the data analysis. All authors contributed critically to the drafts and gave final approval for publication.

DATA ACCESSIBILITY

Data are deposited in the Dryad Digital Repository http://doi.org/10.5061/dryad.d40vr87 (Leigh, Boersma, Galatowitsch, Milner, & Stubbington, 2019). The data provided are summary statistics only, in accordance with the human research ethics' approvals granted to conduct this research.

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